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EECS 522 RF Power Amplifier with Cartesian Feedback

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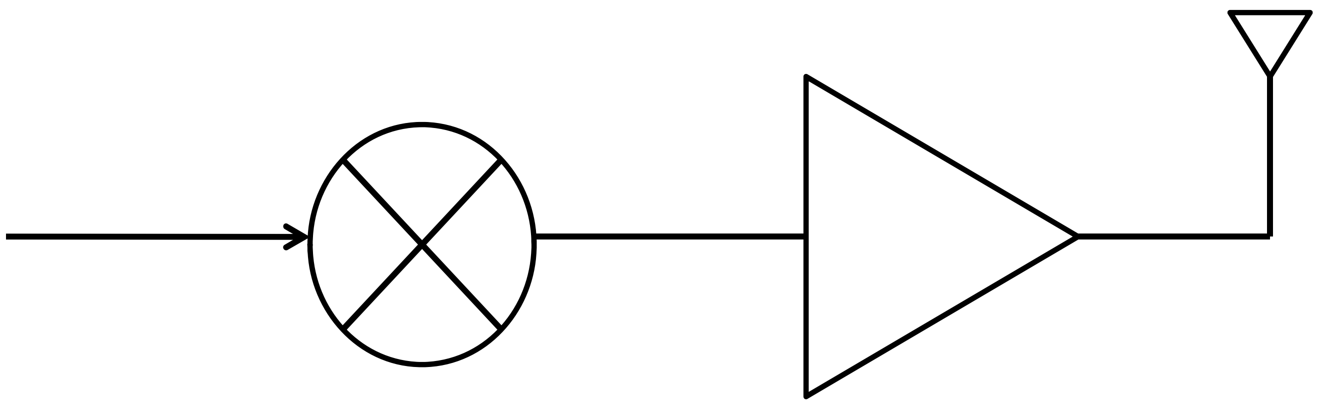
Outline

- Motivation
- Power Amplifier Design
- Mixer Design
- Cartesian Feedback
- System Results

Motivation

- RF transmitter for communication
  - 2.4GHz
- Improve linearization with feedback

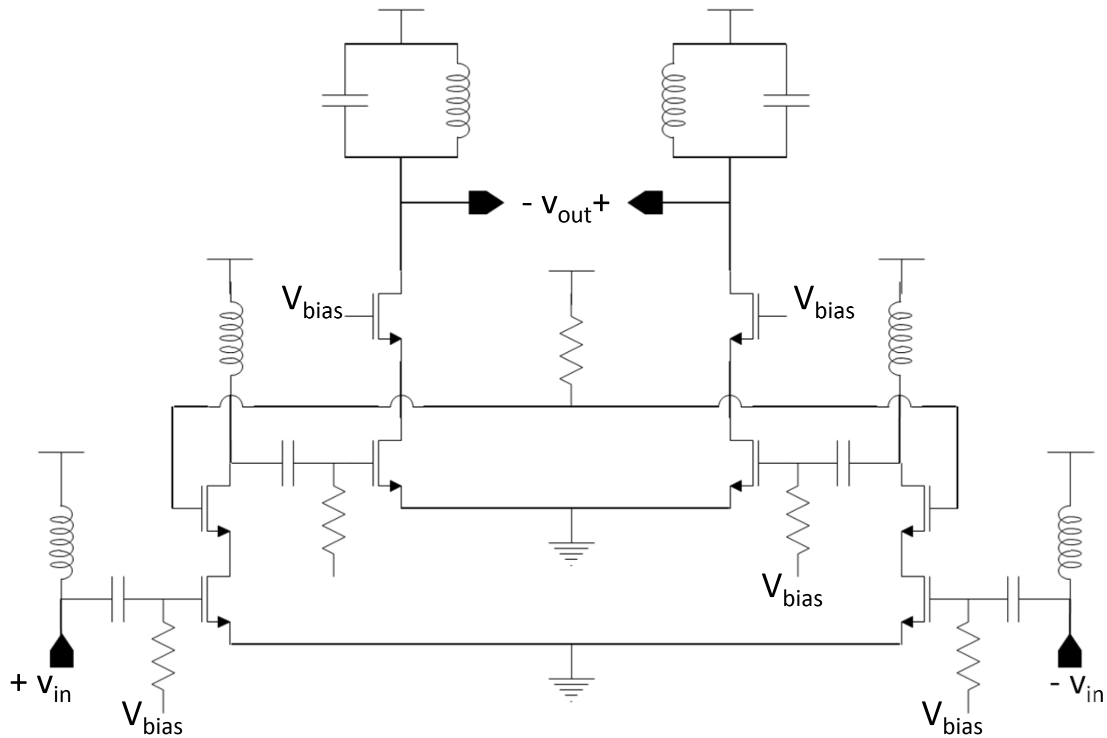


Power Amplifier Overview

- Tradeoffs in PA design:
  - Efficiency
  - Linearity
- Run PA close to saturation for efficiency, then use feedback to improve linearization
- RF PAs have a mixer to up convert the signal from baseband to RF

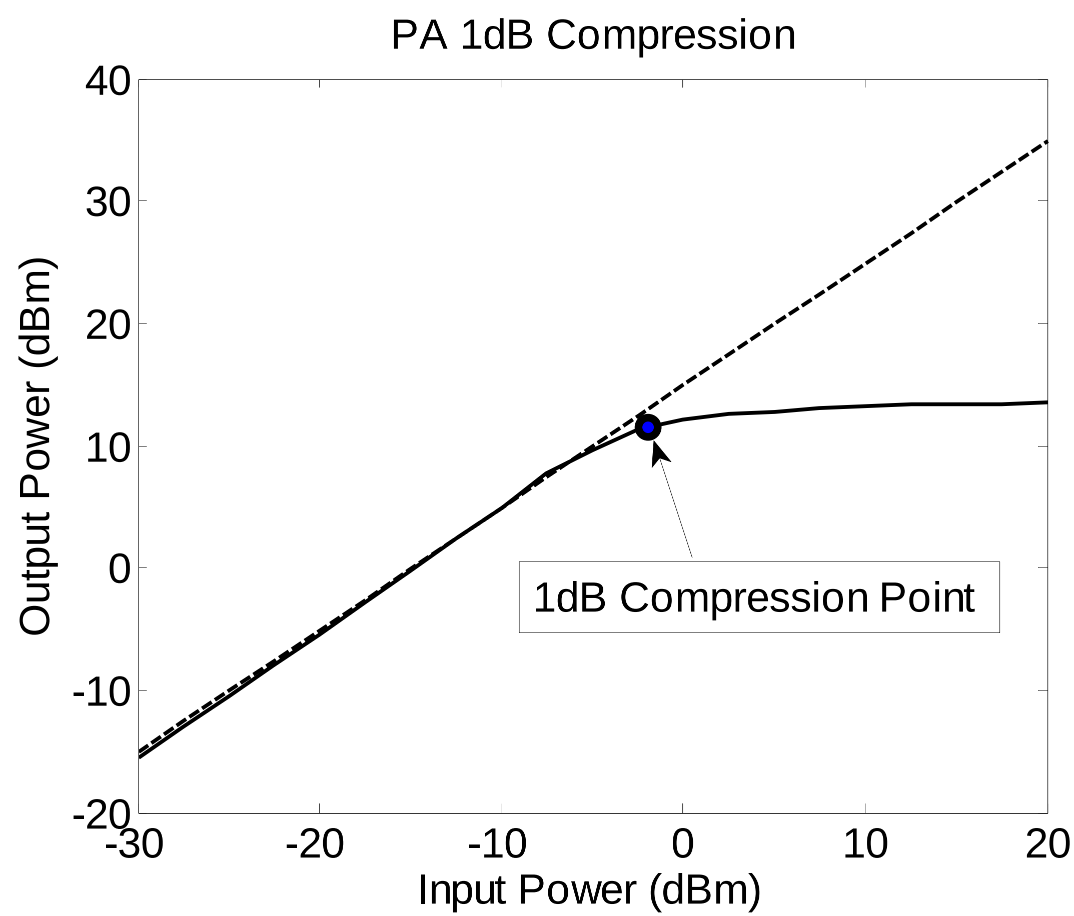
PA Schematic

- Straightforward design
- Power efficient
- Differential to reject RF coupling to power supplies



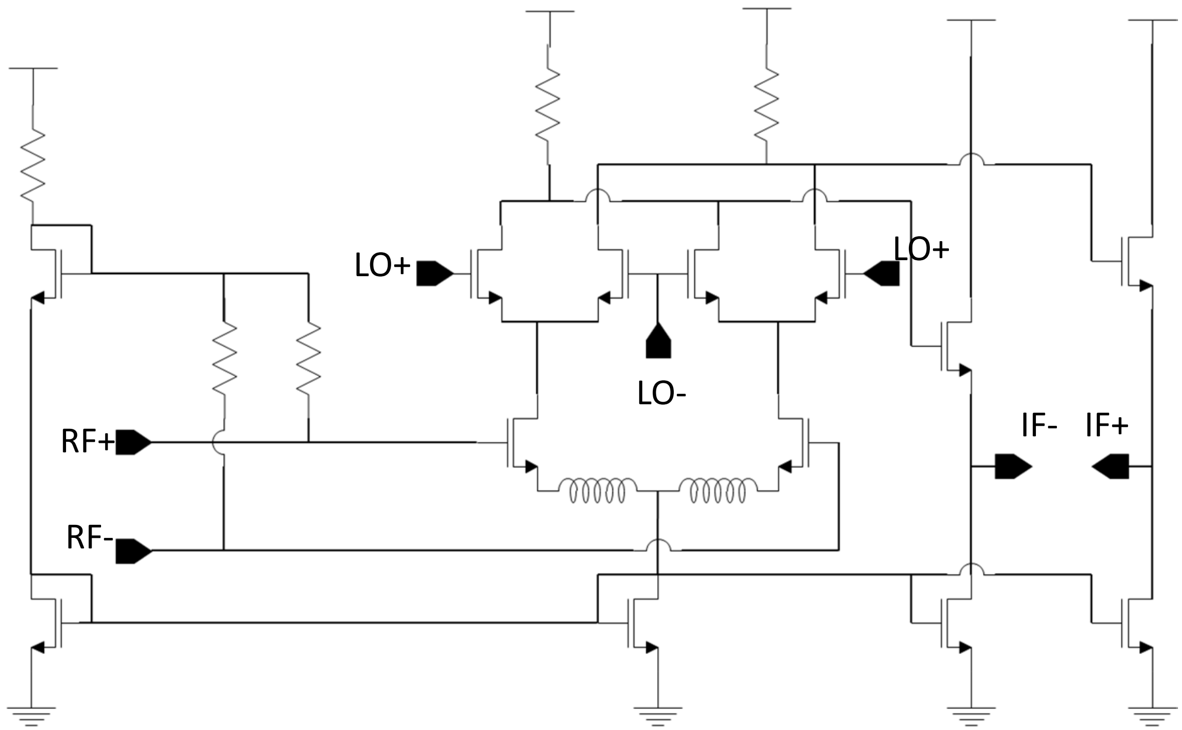
PA Simulation Results

Specification	Results
PAE	48 %
1dB Compression (input referred)	-1.89 dBm
Max Output Power	12 dBm



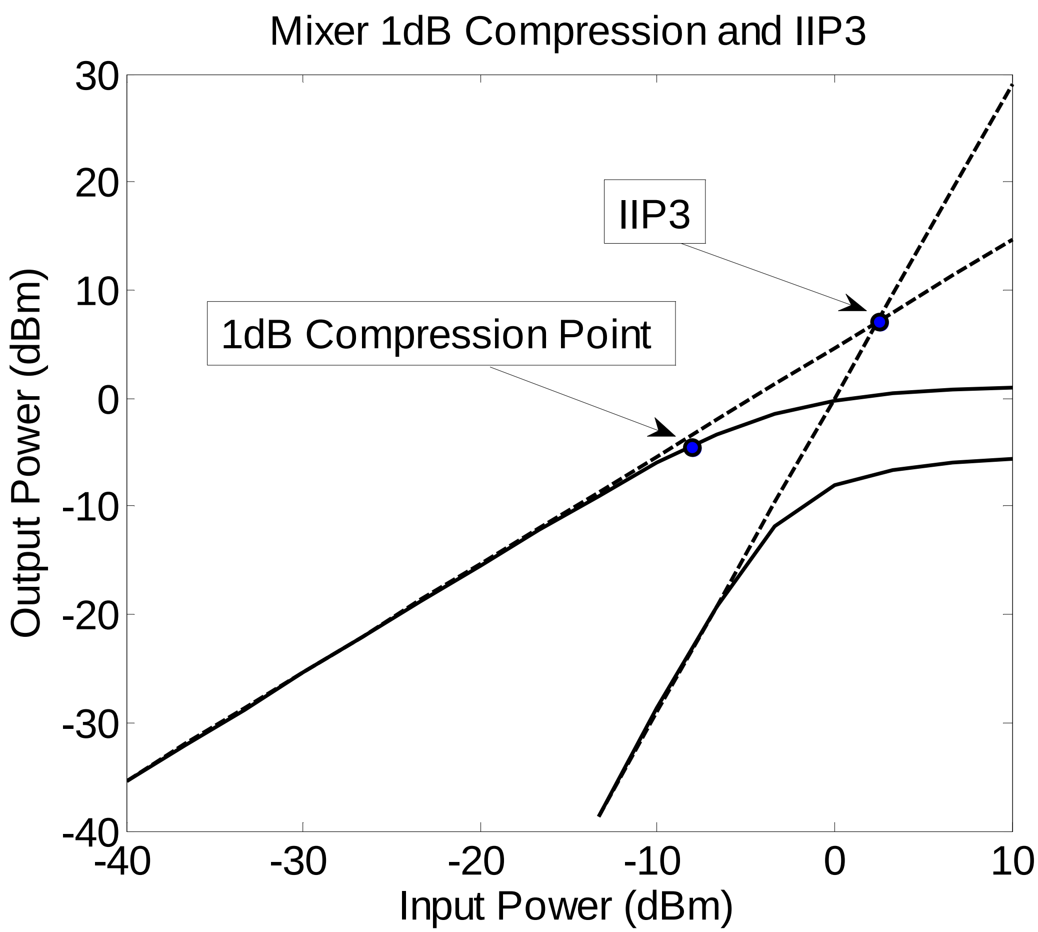
Mixer Schematic

- Better isolation
- LO and RF rejection at IF output
- Higher linearity
- Good suppression of even order spurious product
- Less source voltage noise



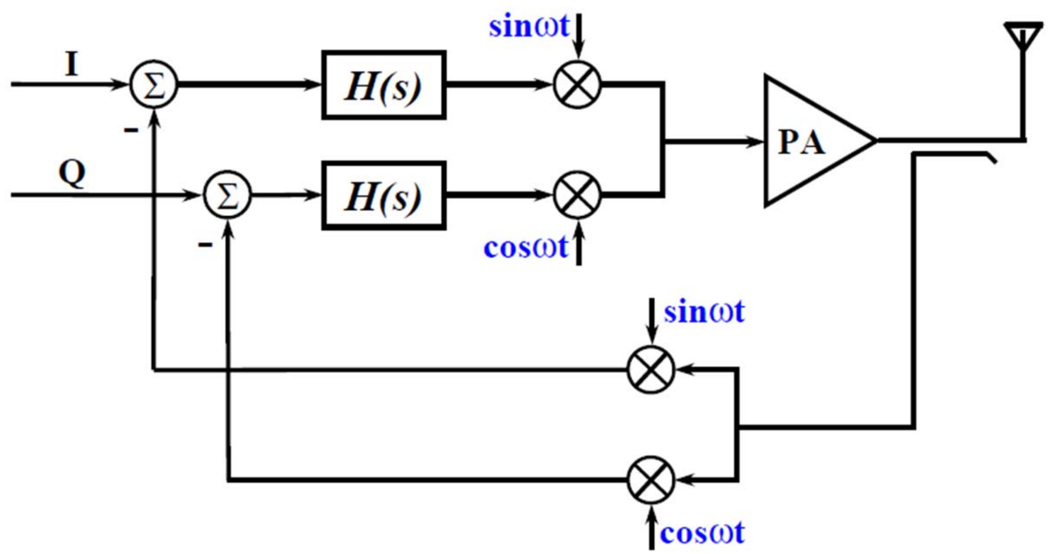
Mixer Simulation Results

Specification	Results
1dB Compression (input referred)	-8.02 dBm
IIP3	1.57 dBm
RF to IF Isolation	77.63 dB
LO to IF Isolation	47.50 dB
LO to RF Isolation	95.88 dB
Conversion Gain	4.65 dB
Noise Figure	21.73 dB
Power Consumption	3.64 mW



Cartesian Feedback

- Improves distortion by increasing the linearity through feedback
- Uses two independent I and Q feedback loops
- Robust for PVT variation

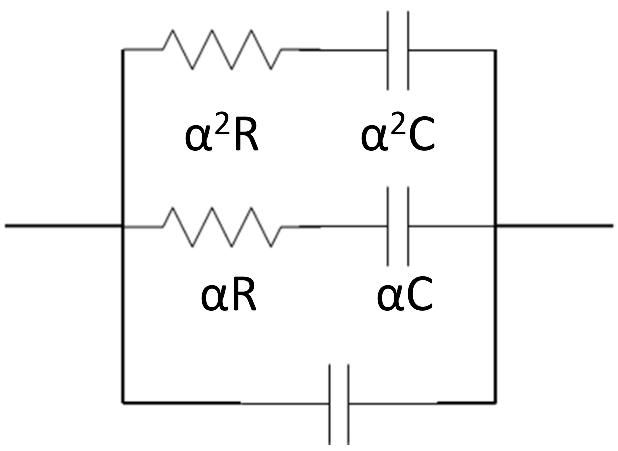


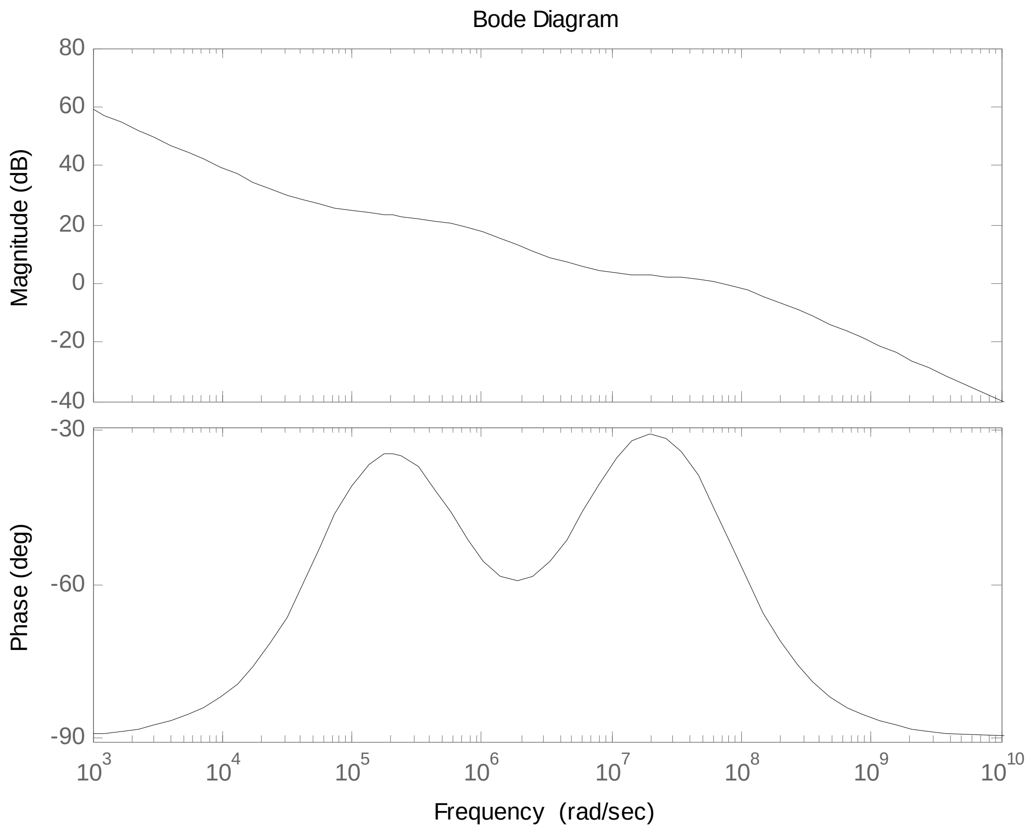
[Dawson]

H(s) Loop Filter

- Slow rolloff
  - 45 deg phase for stability

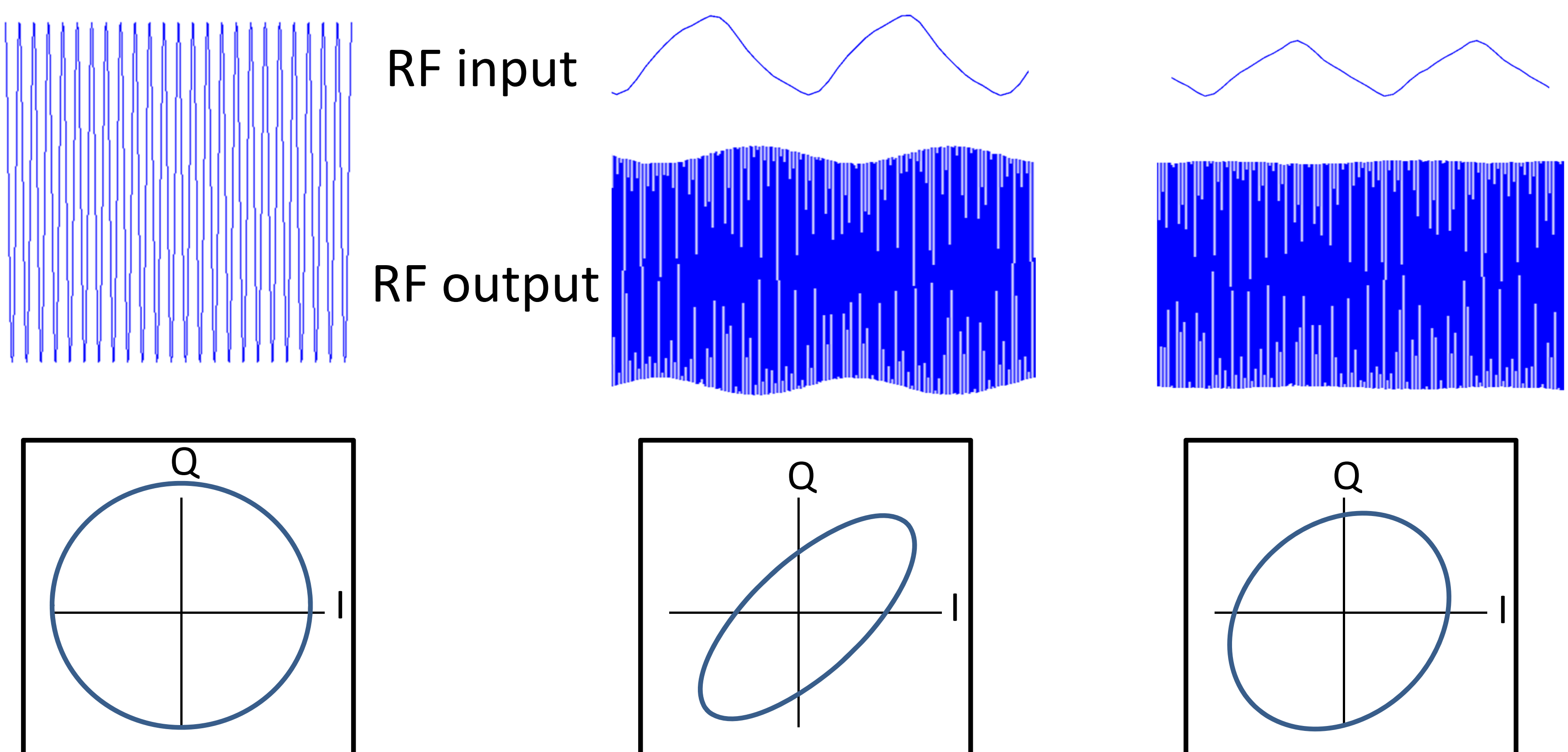
$$H(s) \approx \frac{K}{\sqrt{s}}$$





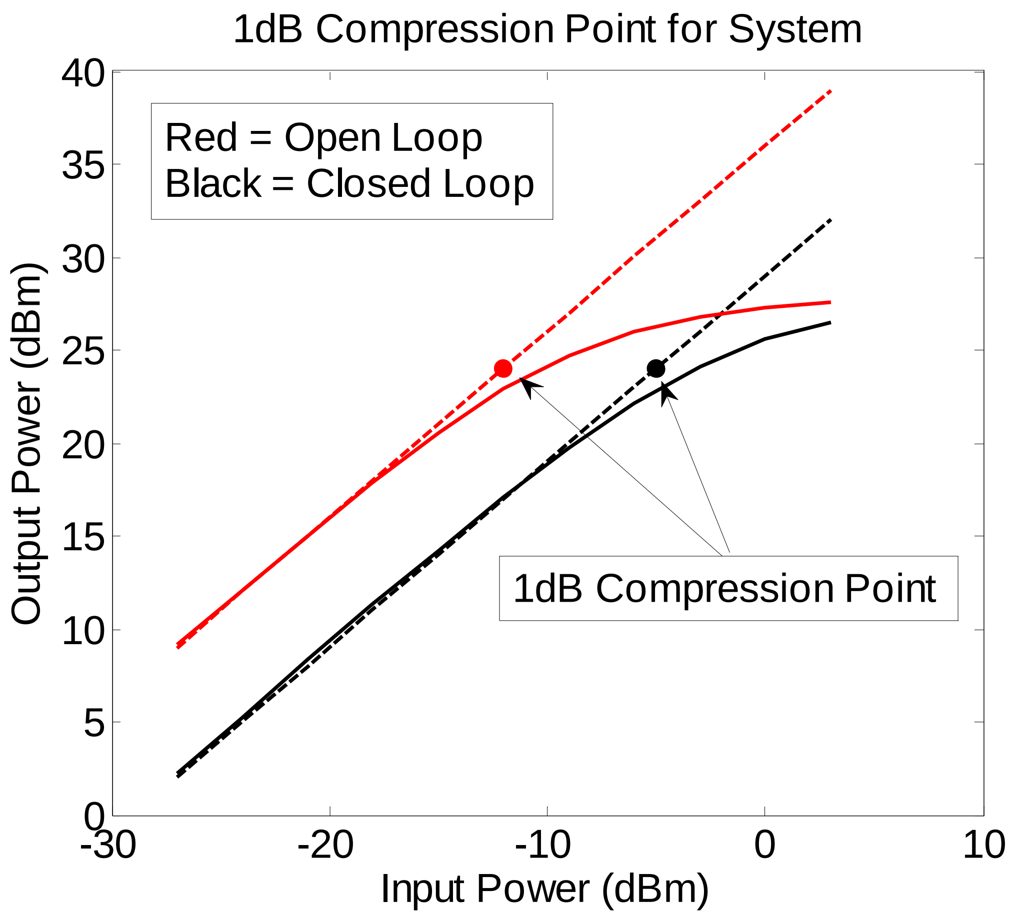
System Simulations

Ideal | Open Loop | Closed Loop

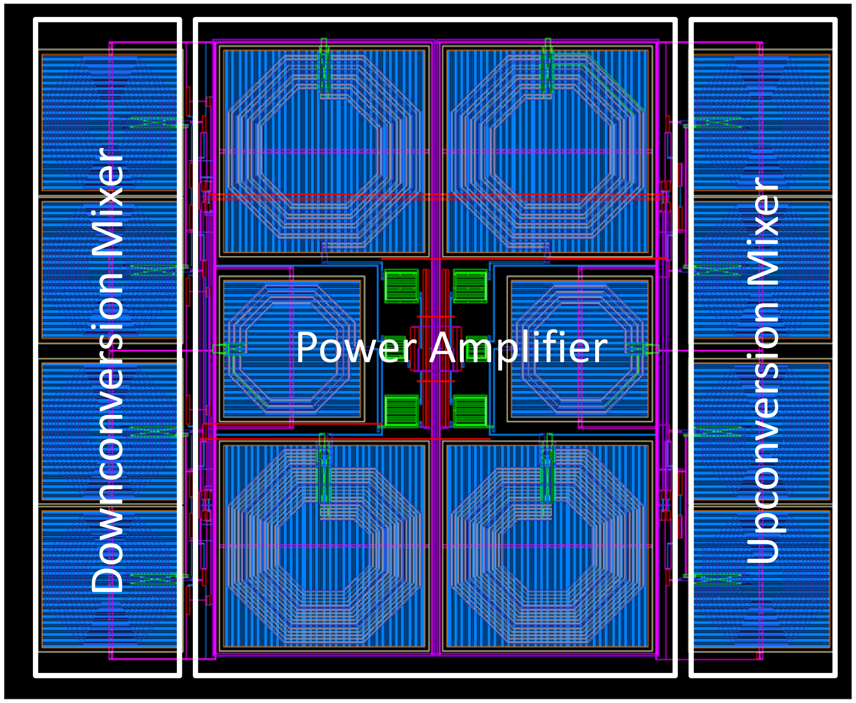


System Simulations

Specification	Open Loop	Closed Loop
1dB Compression (input ref)	-12 dBm	-5 dBm
Max Output Power	24 dBm	22 dBm



Results Summary



Specification	[5]	[6]	Open Loop	Closed Loop
1dB Compression (input referred)	-10 dBm	-31 dBm	-12 dBm	-5 dBm
Max Output Power	21.8 dBm	8 dBm	24 dBm	22 dBm
Area	-	-	$1.15mm^2$	$>1.15mm^2$

Future Works

- H(s) implementation
- Linearity of feedback mixer
- Phase alignment design

Questions?

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References

[1] Chih-Chun Tang; Wen Shih Lu; et al; "A 2.4 GHz CMOS downconversion doubly balanced mixer with low supply voltage," *ISCAS, 2001.*

[2] Palaskas, Y.; Taylor, S.S.; et al; "A 5 GHz class-AB power amplifier in 90 nm CMOS with digitally-assisted AM-PM correction," *CICC, 2005.*

[3] J.L. Dawson, *Feedback Linearization of RF Power Amplifiers.* United States: Kluwer Academic, 2004.

[4] J.K. Roberge, *Operational Amplifiers: Theory and Practice.* New York: Wiley, 1975.

[5] D. Chowdhury; et al, "A 2.4GHz mixed signal polar power amplifier with low-power integrated filtering in 65nm CMOS," ISSU, 2010.

[6] L. Perraud; et al, "A direct-conversion CMOS transceiver for the 802.11a/b/g WLAN standard utilizing a Cartesian feedback transmitter," *JSSC,* 2004.